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Dr. Cheryl L. Shavers, Under Secretary of Commerce for Technology
National Institute of Standards and Technology
Raymond G. Kammer, Director

Suppression Mechanism of Water Mist for Pool Fire

Masahiro Morita
Science University of Tokyo
1-3 Kagurazaka , Shinjyuku-ku , Tokyo 162-0825 , Japan
Tatsuya Minami , Akimitsu Kikkawa
Akifumi Kubota , Hirotoshi Megumi , Hiroaki Suzuki
Center for Research & Development , Yamato Protec Corporation
1951,Nagasao-Dohmae , Kawachi-Machi , Ibaraki , 300-1312 , Japan

ABSTRACT

Suppression mechanisms of water mist for pool fire has been studied for these years.
The purpose of this paper is to conduct the effect of latent heat by water mist compared with that of inert gas against n-heptane fire in a compartment.
The droplets of water mist are in the range of 85 μ m measured by saunter mean diameters.
The relationship of the effect between latent heat and heat capacity under the condition of diluted oxygen. The cooling of fuel has also been discussed.

1. INTRODUCTION

Water vapor is known as a kind of an inert gas for suppression of fire. [1] Water mist is one of good measures of changing water to inert gas for fire suppression agent. Studies on water mist have been conducted from the points of suppression agent against fire for these years by many researchers. [2,3,4]However, water vapor only exists under the condition of physical balance with saturation pressure of water depending atmospheric temperatures.
If a fire in a compartment is large enough compared to the volume of the room, the heat released by the fire will produce sufficient amount of water vapor. However, if the fire is small, evaporated water is small taking the role of cooling room temperatures.
Physical balance between water and vapor make the agent uncertain as a suppressant against fires.

In the present work, the effect of the latent heat has been discussed relating to the relationship between heat capacity and concentration of oxygen for various water flow rate with n-heptane oil fire.

2. EXPERIMENTS

Figure 1 shows the outline of the experimental apparatus. The air flow in the compartment, whose dimensions are 3m long, 3m wide and 2.5m high is controlled by ventilators. The oxygen concentration in the compartment was controlled by discharging nitrogen and air. The oil pan was placed in the center of the floor. Full-cone type nozzles were used. The mean value of droplets were 85 microns in diameter at 0.7MPa measured by Phase Doppler Particle Analyzer (PDPA). The nozzles were set under the ceiling shown in figure 1. The nozzles were located at 2.2m high from the floor level, and the mist were sprayed out into the fire source of oil-pan. The water vapor concentration was calculated from saturated vapor pressure of water at various room temperatures. The concentration of O_2, CO and CO_2 gases were collected at the point of the 80cm apart from the heat source and 50cm above the floor. Vapor and drains were removed prier to measuring O_2, CO and CO_2 gases. The real gas concentrations of O_2, CO and CO_2, were amended by reducing actual water vapor concentration from measured gas concentration

The water mist was discharged when flame temperatures at some points above the center of heat source become nearly steady. The extinguishing time was taken as the duration between initiation of discharging and extinguishment of fire. Complete extinguishment of fire was defined as re-ignition of the remained oil does not catch fire within one minute.

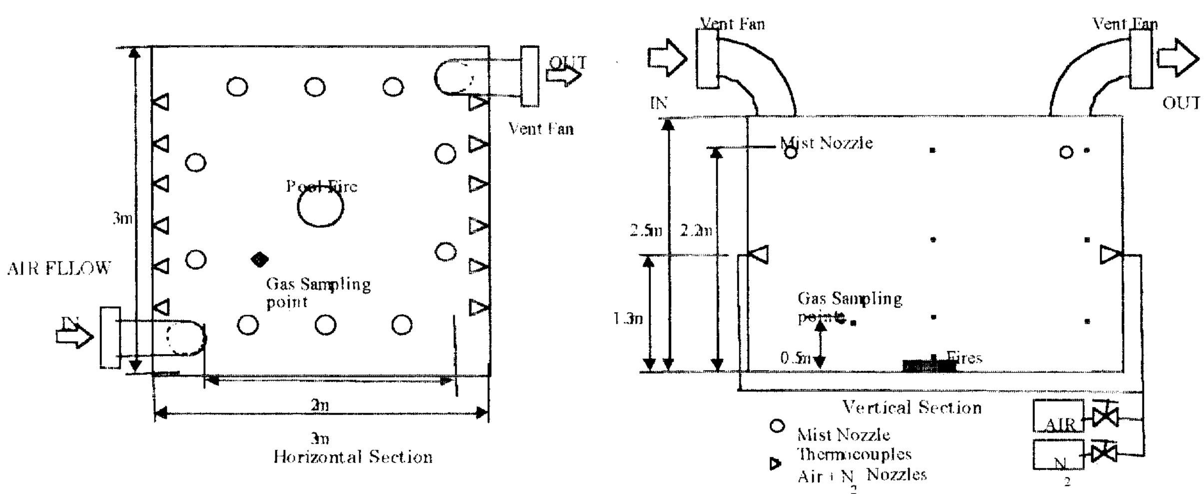

Fig 1. Test Compartment and location of devices.

3. RESULTS and DISCUSSIONS

Figuer2 shows the time-temperature curves of oil fires at the point of 110mm above the heat source pan. The rates of supplying water at the area of the fire source (denoted the flow-rate of water mist) were 0.2 L/m^2/min, 0.4 L/m^2/min, 1.1 L/m^2/min, 1.5 L/m^2/min, respectively and mean droplet size was about 85 μ m in diameter. The flame temperatures show the decayed oscillating phenomena succeeding the fire to be extinguished by water mist. The delayed curves are related to increasing rate of water flow.

Figure 3 shows the relationship between the flow rate of water mist and fuel surface temperatures.The more flow rate of water mist, the fuel surface temperatures become quickly lower. When temperatures reach 60℃, flames are disappeared at any flow rate of water mist.

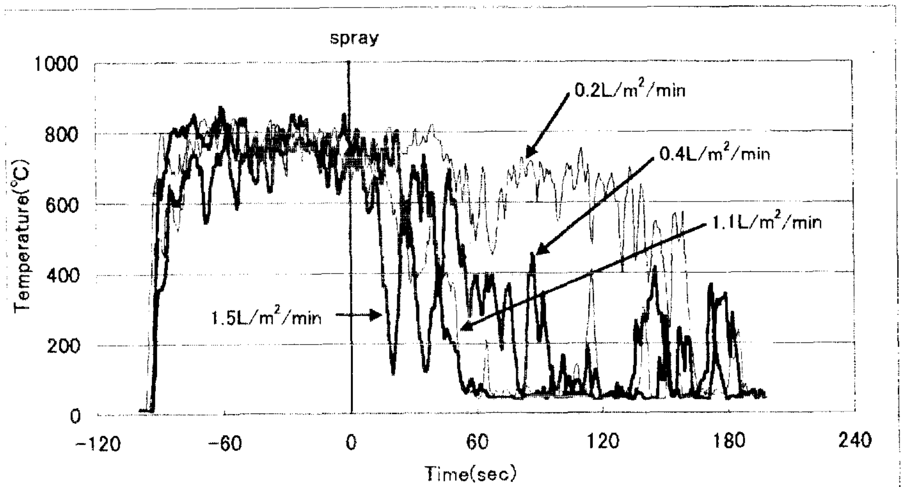

Fig 2 Flame Temperatures

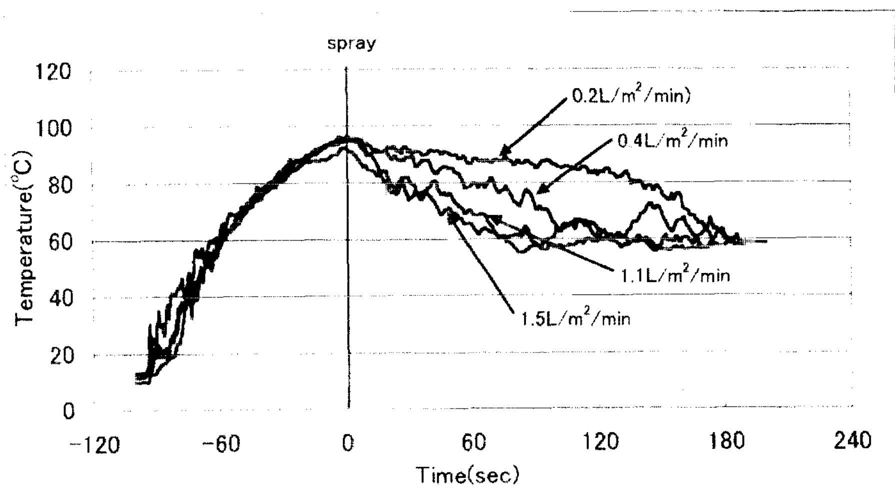

Fig 3 Fuel Surface Temperatures

Flame extinguishing concentrations of inert gases are shown in table 1.[5 , 6] This is known as the difference is due to the heat capacity of each gas for extinguishing flame. Figure 4 shows the relationship between the oxygen concentration and the heat capacity (at 1500K). This suggests that there is a linear relationship between oxygen concentration and the heat capacity for flame extinction by inert gases.

Table1 Flame Extinguishing Concentrations (%) against n-Heptane Fire [5 , 6]

Inert gas	*Flame extinguishing concentration*
CO_2	22%
N_2	33.6%
Ar	43.3%
H_2O	(26%)

H_2O : calculated value assuming 1860K for adiabatic flame temperature

Table2 Heat Capacity of Inert Gases at 1500K

Inert gas	*J / mol / K*
CO_2	58.38
N_2	34.86
Ar	20.79
H_2O	46.98
Air	35.66

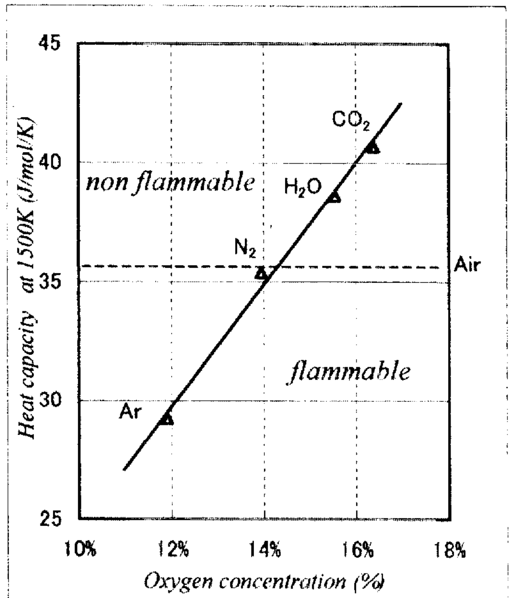

Fig4 The Relationship between Oxygen Concentration and Heat Capacity for Inert Gases

Figure 5 shows the results of water mists tests. The relationship between the real oxygen concentration and the difference of heat capacity as compared to air are shown in Figure 5. The increase of heat capacity is due to the production of water vapor and CO_2. The difference of heat capacity is the difference between heat capacity of air and calculated heat capacity of measured gases, which are water vapor, carbon dioxide, oxygen and nitrogen. In these tests, measured concentration of carbon dioxide and water vapor were 1.2～1.9% and 6～14%,respectively. Therefore, the increase of heat capacity is almost due to water vapor.

The oxygen dilution is due to consumption by combustion and replacement by water vapor and discharged nitrogen. The plotted points show the results extinguished and non-extinguished fires at the conditions. The dotted line shows threshold of extinguished and non-extinguished by water mist. The real line shows flaming limit under the existence of inert gas. This is the same shown in figure 4. This suggests that the difference between the line of flaming limit under the existence of inert gas and extinguishment by water mist is due to increasing flow rate of water. Since the relationship between large heat capacity and oxygen dilution is a mechanism of suppression effect as inert gas. This suggests that the differences between the result of water mist tests and flaming limits under the existence of inert gas are due to latent heat.

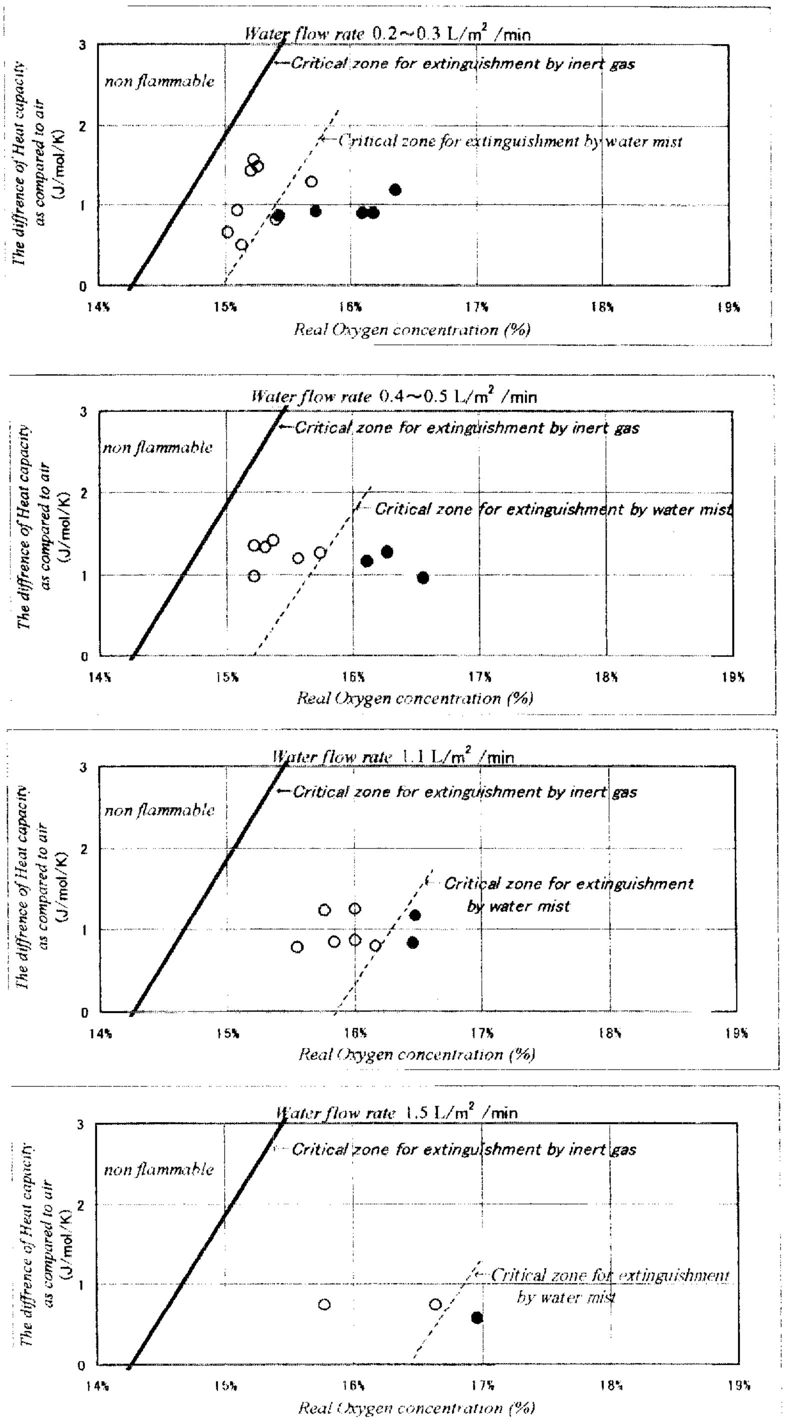

Fig5 The relationship between real oxygen concentration and the difference of heat capacity as compared to air ○ *extinguished* ● *not extinguished*

Figure 6 shows the difference of heat capacity and oxygen concentration related to the water mist tests result and flaming limit under the existence of inert gases. The line suggests the effect of latent heat. When water flow rate is 0.2~0.5 L/m^2/min , the value of latent heat effect is about the same one of the heat capacity by water vapor. If water flow rate becomes 1.1 L/m^2/min , the value of latent heat effect becomes about 2~3 times bigger than that of the heat capacity by water vapor and water flow rate becomes 1.5 L/m^2/min , then the value of latent heat effect becomes about 3~6 times bigger than that of the heat capacity by water vapor.

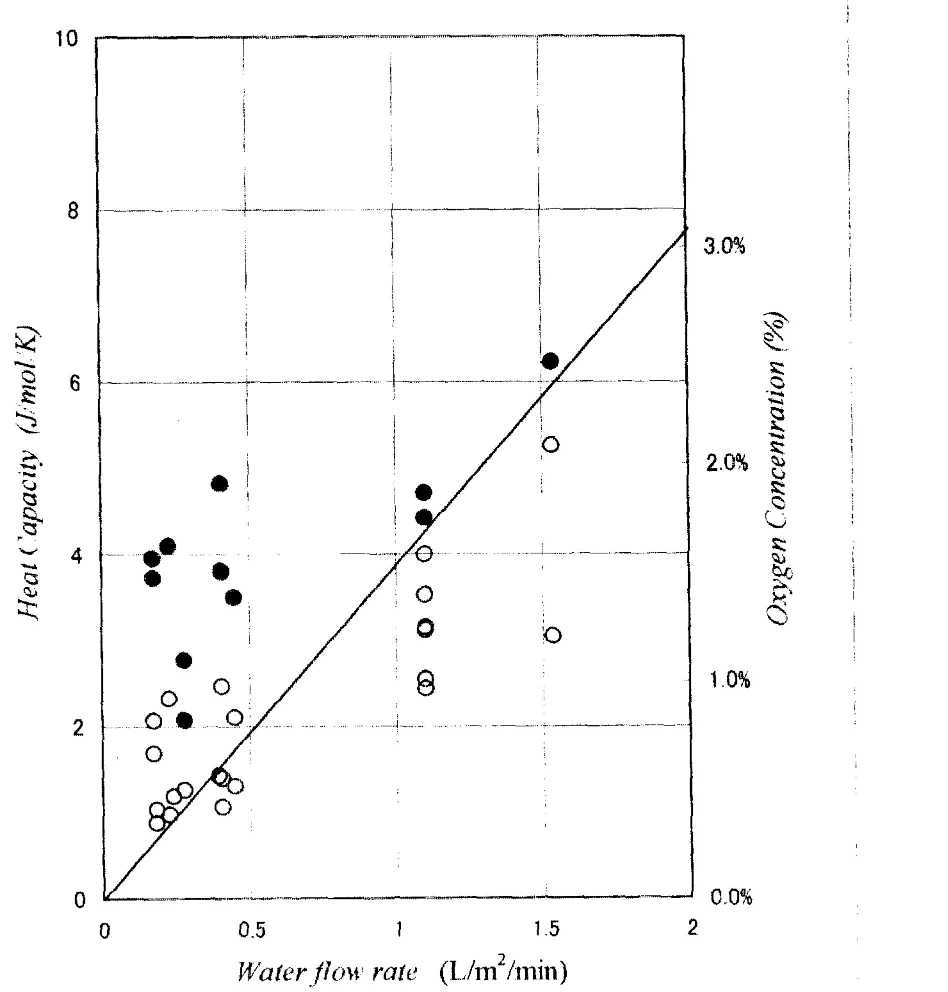

Fig 6 The relation ship between flow rate of water mist tests results and flaming limits under the existence of inert gas in Fig 5

4. CONCLUSION

The effect of latent heat was studied by comparing to flaming zone by inert gases. The suppression factor of pool fire by water mist involves four items, which are latent heat of vaporization, larger heat capacity, oxygen concentration and cooling of fuel. Factor of cooling of fuel seems very small compared to other three factors. Since the relationship between heat capacity and oxygen concentration may take nearly the same effect as that of inert gases.

As the results, the effect of latent heat for various water flow rate were studied. The effect of the latent heat, which increase with water flow rates, is bigger than that of heat capacity which is not big change by water flow rates.

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